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## Farm Waste Disposal Systems

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## **FARM WASTE DISPOSAL SYSTEMS**

and developing methods to deal with the wastes in a non-polluting manner, which will also enable farmers to return the valuable nutrients to the land. In this publication the present available alternatives for waste disposal and criteria for selection of these methods are presented.

Historic Document

# Farm Waste Disposal Systems

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As the attention of researchers, government and the public has been directed toward the preservation of the environment, much concern has been expressed about the disposal of farm animal wastes. Undeniably, farm wastes represent a major source of pollution potential. However, research is proceeding rapidly and developing methods to deal with the wastes in a non-polluting manner, which will also enable farmers to return the valuable nutrients to the land. In this publication the present available alternatives for waste disposal and criteria for selection of these methods are presented.

## The Farm Animal Waste Problem

Farm animal wastes represent one of the largest volumes of all waste materials. It is estimated that such wastes are ten times as large as those produced domestically and five to six times as much as both domestic and solid wastes. However, a large portion of farm animal wastes is deposited directly onto the soil and is thus recycled with little problem. But, the recent increases in animal numbers concentrated under single management, the decline of manure as a competitive fertilizer, the closer proximity of urban areas to production units, and the general demand for up-grading of sanitation practices are a few of the factors which have made animal waste disposal as an acute problem in recent years.

## Recent research on farm animal wastes

Research into the management of animal wastes has been underway for approximately ten years. During this period a series of conferences have indicated the widespread concern in this area. The urgency of the problem has been discussed, as well as the results of various studies on the characteristics, handling, treatment, utilization and disposal of animal manures. Fifty projects related to animal waste research are reported active in 23 Agricultural Experiment Stations in the United States.

Characterization of animal manure has shown it to be a highly concentrated source of organic matter, plant nutrients and micro-organisms <sup>(13, 31)</sup>.

The quantitative character of the waste produced by a specific livestock operation is a function of not only the number and species of animals being raised, but also the system of manure collection and the ration being fed.

\*The numbers in parentheses refer to the citations listed at the end of the paper.

As more sophisticated management and treatment techniques develop, further work on waste characteristics becomes necessary.

Runoff from unroofed cattle feedlots has been studied to determine the quantity and quality of this potential pollutant as a function of feedlot design management and climatic conditions (21). Similar data for other species of livestock being confined in unroofed pens have not been determined. Systems for the collection of cattle feedlot runoff which minimize the quantity of runoff for disposal have been designed (9).

The storage and treatment of livestock manure is accompanied by odors which are objectionable to both livestock producers and the public. Some work characterizing these odors by identification of the component gases has been done (20, 32). Measurement of odors to determine nuisance levels, and to measure progress in odor control have been of limited success (6, 11, 16).

Methods of livestock housing which facilitate manure collection have been evaluated. Sloping floors, flushing gutters, and various designs of slotted floors have been used and have been incorporated into commercial installations. Similarly, manure storage tanks of various capacities, configurations, and structural materials have been constructed. Particularly in northern states, where long term storage is required, it remains an expensive aspect of manure management.

Various devices for the agitation of stored manure and its transfer to cropland have been considered. Centrifugal and positive displacement pumps, augers and vacuum systems for transferring manure from storage tanks to hauling vehicles were studied (28).

Tank wagons and irrigation pumps for the distribution of manure to cropland are also under study (7). These systems are currently limited by climatic conditions, odor problems, large land requirements and expense. The escape of toxic gases during manure tank agitation has been of concern to many operators, and has also resulted in numerous animal deaths (33).

Various schemes for the treatment of animal manure prior to utilization or disposal have been proposed. Lagoons were found to effectively store manure, but did not produce an effluent suitable for discharge into streams. In addition, lagoons have been sources of objectionable odors (4, 8, 12, 19).

More sophisticated anaerobic treatment units have been considered, but have not been adopted by the livestock industry (30).

Aerobic treatment of animal manures has been of considerable interest during the past three to five years. Aerated lagoons and oxidation ditches are effective for minimizing odors from waste treatment; however, they do not produce effluents suitable for discharge to surface watercourses (5, 10, 14, 27). Effluent from these units is sufficiently high in organic matter, plant nutrients, and retains sufficient color to make land application the most widely used practice for disposal.

Research is just beginning to study utilization of animal manures in ways other than direct soil enrichment. Refeeding to livestock (1) and growth of economically useful plants are two examples of this approach.

Additional possibilities exist and are receiving research attention. Alternate methods of manure processing, which are under consideration, include dehydration and incineration (2). These methods are still in exploratory stages and must be pursued through the development of usable equipment and the planning of auxiliary equipment and management techniques.

The use of soil as a recipient for animal manures is continuing to receive attention. More sophisticated methods of manure application, more effective use of the nutrients, and use of the soil as a high capacity treatment system are being investigated (3, 25).



The work in animal waste management has been expanding rapidly and an increasing number of papers are published annually. Reviews of these papers are also published annually for easy access (22, 23). Loehr (18) has also published a comprehensive review of animal waste research, while Muehling (24) prepared a review of research done on swine wastes.

## Rationale of returning wastes to land

### Returning to Land Versus Not

A frequent question is: Why not return the animal wastes to the soil? If the wastes containing chemicals and organic matter are returned to the soil properly, they will represent no more pollutational capacities than they did before they were used to produce a crop, which was fed to the animals, and which in turn was defecated to become a waste.

The key is in the phrase "returned to the soil properly." This embodies all the facets such as (1) allowable quantity, (2) time of application, (3) effect on soil, (4) possible pollution of ground and surface water, (5) odors, and a number of other factors.

In farm animal waste handling and disposal, economics is probably the largest single factor. Dr. Leon W. Weinberger (35) made the following statement, "Unfortunately we have confused our technical ability in solving a problem with the costs associated with solving the problem, and who should be paying the costs for pollution control. It can be adequately demonstrated that if we could make a profit out of pollution control, adequate pollution control would be accomplished."

Who is to pay for adequate animal waste management and can the cost be passed on to the consumer? If there were to be a uniform increase in the cost of eggs, chicken, dairy products, or meat, the solution probably would be easier. The consumer ultimately will bear the cost.

### How Much Can be Returned to the Land?

Based on research at the University of Wisconsin, approximately 250 pounds of nitrogen can be added to each acre of the soil each year without unduly polluting it.

On this basis, the wastes from various species may be returned to the soil as shown in Table 1. These figures are estimates, based on the average animal waste production and their characteristics (18) known at the present.

**Table 1. Waste Production and Characteristics for Farm Animals**

	Assumed Avg. Wt.	Daily Manure Production % Body Wt.	Annual Production tons	Pounds/Ton			Pounds/ Animal / Year			*Animals per Acre
				N	P	K	N	P	K	
Dairy Cattle	1000	8	15.0	9.0	2.0	5.0	135	37	60	4
Beef Cattle	900	6	9.7	10.0	4.0	8.0	97	39	87	5
Swine	100	8	1.5	10.0	2.8	7.6	15	4.0	11.8	33
Poultry	5	7	0.064	25.0	18.0	12.0	1.6	1.2	0.8	300
Sheep	100	7	1.3	28.0	4.2	20.0	36	5.5	26.0	15

\*This recommendation is based on the generally accepted assumption that 50 percent of the nitrogen will be lost by volatilization, denitrification, etc. before the manure can be applied to the land. Thus, of the 500 pounds of nitrogen produced by this number of livestock only 250 lbs. will remain in the manure applied to the soil. If the crop is one that removes more nitrogen, e.c. Reed's Canary Grass, more could conceivably be applied.

Even though wastes may not be returned to the soil—for example: they may be placed in an anaerobic lagoon—there may also be some relationship between the acceptability of the odor produced and the proximity to people. Therefore, if the land area is sufficiently large for the soil to take the wastes, it may be large enough to provide adequate distance between odor-producing organisms and people living in the vicinity.

There are two distinct categories of farm animal production units: (1) the unit that has sufficient land for satisfactory disposal by crop utilization and (2) the unit that does not have sufficient land for satisfactory disposal by crop utilization.

At the present, no differentiation is made between these two groups. For example, the anaerobic type of lagoon is probably satisfactory for the disposal of wastes on a small scale, where distances are sufficient for satisfactory dilution of the noxious gases. But, where the production unit is quite large, and the land is small, anaerobic lagoons are probably not satisfactory. However, present recommendations by various agencies make no mention of this.

## Some Waste Handling Methods

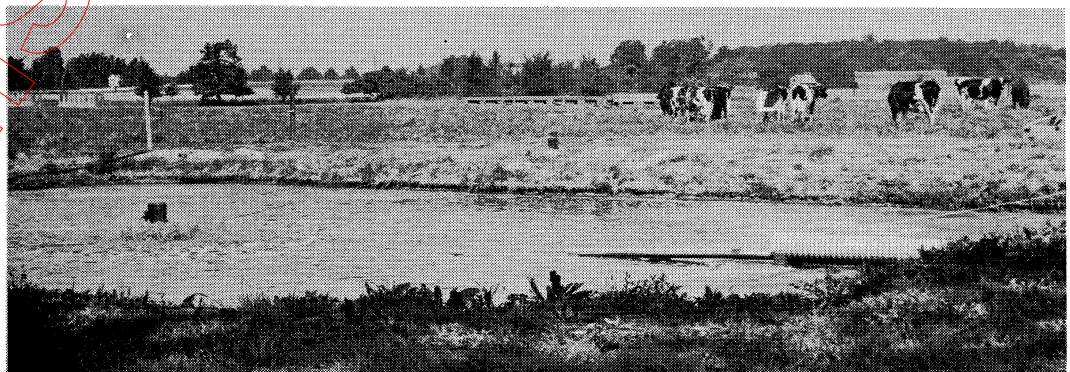
### Lagoons

The name, lagoon, is an all-inclusive term commonly given to a water impoundment in which organic wastes are stored, stabilized, or both. Lagoons may be described by the predominant biological characteristic (aerobic, anaerobic, or facultative); by location (indoor, outdoor); by position in a series (primary, secondary or other); and by the organic matter accepted (sewage, sludge, manure, etc.).

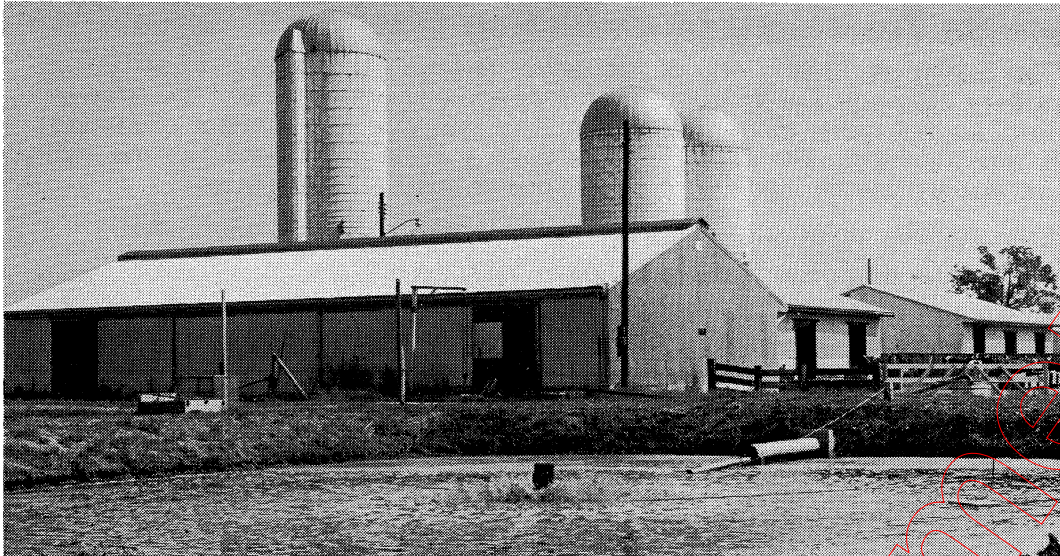
However, lagoon's adaptation to the treatment and storage of farm animal wastes is of relatively recent (fifteen years ago) origin. Because of their abuse and misuse, and because of the lack of understanding of their true functions, lagoons are somewhat controversial. Most farm animal waste disposal lagoons were supposed to have been what was formerly called "oxidation ponds"; but over-loading resulted in its functioning more as a facultative (both aerobic and anaerobic bacterial action) lagoon with noxious odors.

**Aerobic lagoons or oxidation ponds.** Aerobic lagoons are shallow basins excavated for stabilizing wastes (animal manure) by storage under climatic conditions that favor growth of algae: namely warmth and sunshine. Bacterial decomposition of the wastes releases carbon dioxide; heavy growths of algae develop; ammonia and other plant-growth substances are used up; and a high level of dissolved oxygen is left.

If aerobic lagoons are made three to four feet deep and hold the wastes for four or five weeks, the organic material is stabilized and a satisfactory reduction in the oxygen demand is observed. Unfortunately, the mixed liquor in the lagoon still contains many nutrients that may pollute the streams if should they be discharged. The effluent may, however, be irrigated directly onto crops and soils without any undue problems.







The biggest obstacle to using this type of lagoon is the low loading rate. For it to operate satisfactorily, the loading rate is restricted to 45 to 50 pounds of Biological Oxygen Demand (BOD) each day per acre of lagoon. This means that one acre of such a lagoon will only take care of the manure of 150 hogs weighing 125 pounds, 20 dairy cows weighing 1500 pounds, or 30 beef cows weighing 900 pounds. Few lagoons in use on farms were loaded so lightly. Thus the oxygen supply was depleted, and the lagoons ceased to function aerobically.

Once the lagoon goes "sour" it produces vile odors. To sweeten (raise the pH) it must be treated with lime, anhydrous ammonia or some other acceptable alkaline substance. The feed (manure) added daily must also be brought down to an acceptable level.

Temperature is an important factor in the proper functioning of aerobic lagoons. Generally, the higher the temperature, the greater the growth of the bacteria. Thus lagoons "work" better in warm climates.

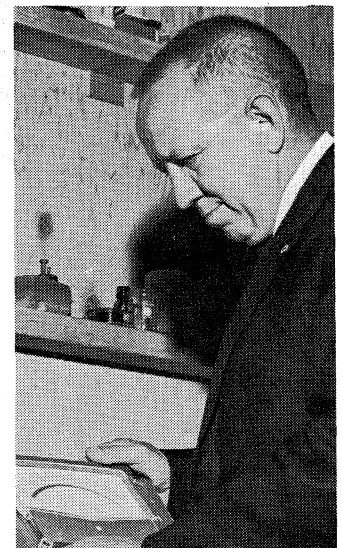
**Anaerobic lagoons.** Anaerobic lagoons function without free oxygen available in the liquid. Free oxygen actually inhibits bacterial growth and multiplication. The bacteria obtain their required oxygen from proteins and other materials that they decompose.

The anaerobic lagoon produces many gases, a number of which are odorous. However, when anaerobic lagoons are functioning properly, they do not produce as many of the highly objectional gases (carbonaceous gases with sulfur attached) as they do when they go "sour" (acid) or facultative.

Since the anaerobic lagoon is not dependent on oxygen from algae or wind action, it may be much deeper than the aerobic lagoon. The depth is probably related to the temperature of the subsoil, but present recommendations (17) indicate lagoons with depths of 15 feet or more may function entirely satisfactorily. The function is related to volume in the anaerobic lagoon, instead of the surface area, as in the aerobic lagoon; but temperature is also important, with warm climates again furnishing the more favorable condition for good action or decomposition.

Typical recommendations call for the anaerobic lagoon to have a volume of two cubic feet per pound of swine, 1 cubic foot per pound of dairy or beef cattle, or three cubic feet per pound of chickens.

Anaerobic lagoons may serve as large storage and "surge" tanks during winters, with the effluent applied by irrigation during the summer. It has been reported (15) that water from the top of anaerobic lagoons gives off little discernible odors.





## Aerobic Treatment by Oxidation Ditches

The oxidation ditch is one of the newer (within the past five to six years) treatment methods. For a short time it was actually portrayed as "the answer" to farm animal waste disposal problem. This was due to a number of individuals overestimating the capabilities of such a system. However, in the rush to be the first, some individuals oversold and misused the system.

Some of the major considerations in use of the oxidation ditch, are:

1. Aerobic treatment lessens the odors of wastes.
2. Some odors will still exist as fecal matter adheres to slats, floors, etc.
3. Forty to fifty per cent of the solids are removed by decomposition, but the rest remains as bacterial cell walls, undigested feed and minerals.
4. Much unstabilized material remains in wastes that have been treated for only a short time. For example, in the continuously operated ditch (one in which materials flow out as new wastes flow in), some raw wastes flow right on through with little or no treatment. These raw materials will cause odors in storage lagoons and during spreading.
5. Economically, oxidation ditches do not appear to be favorable at the present. Purchasing and installation costs are sizable, and cost of operation appear to make it prohibitive. This is particularly true when one considers that it is accomplishing only a part of the job.
6. The partially stabilized mass of wastes (sludge) must still be handled in some manner. It cannot be discharged into a surface stream, since it contains far too many nutrients, solids and unstabilized materials. So the final disposal has only been delayed, although aided by a reduction of odor.
7. Research to date has dealt only with segments of the treatment of wastes by oxidation ditches and their final disposal. Some overall system must come before its acceptance.
8. If the oxidation ditch can be integrated into some automatic system which places the wastes back on the land with a minimum of cost and labor, it may then be a satisfactory waste treatment and disposal systems. If placement in a lagoon is considered final disposal, then these systems may be easily adapted to livestock production systems.
9. The oxidation ditch may use a pit similar to that for liquid storage. Therefore, it may be advisable to build the storage pits in such a manner that a rotor aerator can be installed later.



## Aerobic Treatment by Mechanically Aerated Lagoons

The mechanically aerated lagoon performs many of the same functions as the oxidation ditch. In addition to maintaining an odorless condition, the ditch serves to aerate the materials for a long period so they become completely stabilized. Again, there is some odor from fresh wastes which stick to the floors inside the structure or on the feeding floor. Essentially, there is little difference between the shape of the mechanically aerated lagoon and that of the typical anaerobic lagoon.

The mechanically aerated lagoon may be quite large, serving as a "surge" tank for runoff during the winter prior to irrigation of the water from the top of the lagoon to soils and crops in the spring and summer.

Malfunctioning of the aerator is not so critical in the outdoor manure lagoon as in the oxidation ditch. Gases do not cause toxic conditions in the house, foam is not a problem, and additional moisture is not added to air in the building.

## Liquid and Solid Spreading

The return of animal wastes to the land by liquid or solid spreading may still be among the best methods of reclaiming and disposing of wastes. The

nutrient value is not large, but once materials are spread in a satisfactory manner, odors cease and the nutrients become available for absorption by the plant.

Pollution of surface and ground waters is eliminated if wastes are spread properly and at the right time of the year. Research to date indicates that animal wastes may be placed on soils year after year as long as not more than 250 pounds of nitrogen per acre are added. Additional research is needed to verify this recommendation, however.

**Liquid Injection or Quick Plowdown.** A new liquid injector which places the wastes directly behind the liquid manure wagon in a slot cut by a steel point has been developed by a number of companies. The point is located in front of the tire, which compresses the soil or turf, thus sealing the slot. Odor levels appear to be low.

The placement of liquid manure in a furrow which is quickly covered has also proven to be a satisfactory method for applying liquid manure.

## **Drying and Recycling**

At Michigan State University poultry wastes are being dried, reconstituted with feed, and fed to chickens, cattle and hogs on an experimental basis. To date, it has proven to be a satisfactory feed constituent when not mixed in a greater ratio than three parts waste to seven parts feed. Research has not yet established limits for this treatment, however.

Drying is difficult and expensive. It is not beyond the scope of operation, but it can add more costs than can be justified by returns. For example, a poultry production (laying) company which went to a drying system for chicken wastes to stay in business, has found it to be neither an economical system; nor trouble free. However, it has stopped the odor of the lagoon, and the poultryman is producing a material that is not obnoxious to handle, store or convey. It is a saleable product but demand is low.

## **Deep-pit Compost**

Another method of handling poultry manure in the dry state involves collection and storage in a deep pit. This is a relatively new method and one that shows much promise. Manure is allowed to collect in an 8-10 foot pit until cleaning is required. The pit contents must be kept relatively dry for the system to be successful, and for the prevention of odors.

Additional ventilation in this type of house seems to work well for keeping the manure dry. Some houses are now being designed with exhaust fans below cage level to increase air flow in the pit area, and with the storage pit above ground level to insure against ground water in the waste material. The need for this may be limited to areas where the water table is extremely high.

Disposal from deep pit houses may not be required at frequent intervals if ideal conditions exist. None of the houses of this type has been in use long enough for anyone to determine how long cleaning may be delayed. Poultrymen who are using this type of housing have found that decomposition or composting reduces volume significantly after one or two years of use. After the composting action begins, build-up is very slow.

Some authorities feel that because of the reduction in volume from the composting action, the house may be obsolete before the pit needs cleaning. If cleaning is required, the long-time accumulation would result in a rather large volume of waste which requires disposal. It must be noted, however, that because of the composting action the volume would be substantially less than the total volume which would have been removed by frequent cleaning of the house over the years. Observations to date indicate that the rate of build-up may not be more than four to six inches per year.

## Odor Control

Odors have been cited by many as the most severe problem at present. This may be true for the small or moderate size operator who is disposing of the swine manure by lagooning or spreading. In either case, the odors can be greatly reduced by some relatively inexpensive methods.

**Addition of Chemicals**—Some of the more common chemicals that will reduce odors while spreading are ammonium nitrate, anhydrous ammonia, powdered lime, chlorine, sodium hypochlorite, and activated charcoal.

The first two, ammonium nitrate and anhydrous ammonia, are the most highly recommended for farm use. The addition of one to two pounds of ammonium nitrate per one hundred (100) gallons of liquid swine wastes, just prior to mixing and spreading, will greatly reduce the accompanying odors. Ammonium nitrate is a hydrogen acceptor, and in its chemical action liberates oxygen, temporarily inhibiting the anaerobic bacteria.

Most chemicals change the manure from an acid condition to an alkaline one. Thus, acid-forming bacteria are inhibited, and the odorous gases are stopped. There may still be an ammonia odor with the manure, but it is not so objectionable as hydrogen sulfide, sulfur dioxide, and the mercaptan gases.

Lime usually acts more slowly than anhydrous ammonia, but it will perform similarly.

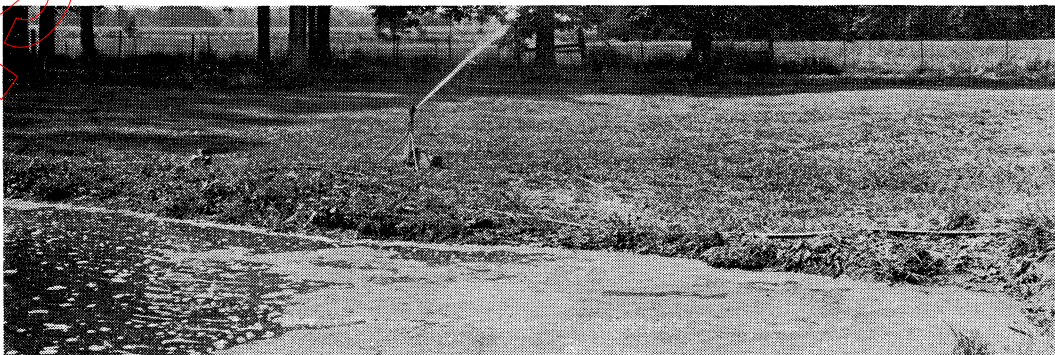
The chlorine chemicals are strong oxidation-reduction agents which release oxygen for the oxidation process. Thus, the system is temporarily changed to one which inhibits anaerobic bacteria and promotes aerobic action. Therefore, odors are greatly reduced. Also, chlorine, in sufficient quantities, is toxic to bacteria, greatly inhibiting their activity and gas production.

## Summary

The animal producer must consider many factors when selecting a system of animal waste disposal. Among the alternatives are:

**Returning Directly to the Land**—Returning manure directly to the land, either as a solid or liquid, is a good method if it can be fitted into the operation. For the producer who has sufficient land available, it will probably be the most economical, if the value of the fertilizer in the manure is considered.

**Lagoons for Complete Disposal**—The lagoon recommended by the Midwest Plan Service (9) is one which has about 400 cubic feet per hog and 11 or more feet in depth. This may be the "best" answer. By use of this lagoon for irrigation purposes, and desludging from time to time (which may be done through some irrigation systems), it should be satisfactory for many years of storage and operation. If by chance, the lagoon becomes "overloaded" and malfunctions, producing undesirable odors, a treatment with anhydrous ammonia or some other alkaline buffer will help return it to a "sweet" condition. In a lagoon of this type, all nutrients are not lost,





since much remains in solution and in the sludge, which can be recovered by spreading on the land.

**Combination of Storage Pits Plus Lagoons**—A system that is being tried by some producers, and one that appears to have considerable merit, is a combination of pits to store the solids until spreading is convenient and lagoons for the liquids. One method of operating this system is to construct an overflow which permits the liquid to flow from the pit to the lagoon once the storage becomes full of both the liquid and solid mixture. Experience has shown that the solids generally settle to the bottom. Therefore, separating them is not difficult. Such a system accomplishes several things:

- (1) reduces the needed storage capacity,
- (2) reduces the size of lagoon needed,
- (3) permits a more flexible schedule for spreading,
- (4) Improves the quality of manure, even though some nutrients are lost in the liquids going to the lagoon,
- (5) lessens lagoon odors,
- (6) may be usable for a much greater period if only liquids are permitted to flow to the lagoon,
- (7) yields a much higher quality effluent, which then may be more suitable for discharge into a natural drainage ditch, and
- (8) can irrigate from the lagoon to recover some of the nutrients.

As with all systems, there are a few disadvantages:

- (1) solids are likely to become compacted, and may require considerable stirring and mixing before they can be readily pumped by a vacuum wagon,
- (2) some nutrients are lost to the lagoon, and
- (3) dual costs exist for both a lagoon and storage.

With a lagoon and storage combination, it is recommended that storage and of at least one-half gallon per hog per day be provided for growing-finish-ing hogs. This is about one cubic foot for each sixteen hog days or, assuming a 96 day feeding period, this would be six cubic feet per hog for the entire time. The remainder of the wastes and liquids would be discharged to the lagoon.

The lagoon size in this case could be cut to one-fourth to one-third of the recommended lagoon. However, if the area where the lagoon is constructed is sufficient, keep the size as large as possible.

The solids in storage should be spread as soon after removing the hogs as weather and soil conditions permit. This will insure a maximum return from the wastes and will prepare the system for a new herd.

**Criteria for Going to an Aeration System**—At present, the main factor in favor of going to an aeration system is control of odors. If odors are not a problem, then it is recommended that producers stay with liquid or solid spreading, lagoons, or a combination of the two.

Aeration of wastes will not control all odors of a swine production unit. Fresh manure on floors, slats and around the farm still produce an objectionable odor.

**Aerated lagoons** make it possible to control odors with a much smaller volume than is normally possible. Present recommendations for unaerated lagoons call for about 400 cubic feet of volume per hog finished per year. Charles E. Clark (4) sanitary engineer of the Illinois Department of Health, recommends an acre of lagoon, five to seven feet deep per 275 hogs. This is a volume of about 1000 cubic feet per hog. By the use of aeration devices, such as a floating aerator, the volume can be reduced greatly. Also, the lagoon can be increased in depth and, therefore, reduced in size. For

example, for these 275 hogs, the volume of the aerated lagoon could be reduced to one-fourth this amount, and the depth could be three times as great.

Using these criteria (250 cubic feet per hog and an 18 foot depth), the size of the lagoon for 275 hogs would be slightly under 4,000 square feet or one-tenth acre. However, to aerate this lagoon properly, a two horse-power floating aerator or its equivalent (one that supplies about six pounds of oxygen per hour) would be required.

A two-horsepower motor requires approximately two kilowatt hours per hour. Then  $2 \text{ k.w. hrs./hr.} \times 24 \text{ hrs./day} \times 120 \text{ days} = 5,760 \text{ k.w. hours}$ , which at 1.5¢ would give \$86.40 power cost. This is slightly over 31¢ per hog for power costs. Equipment and installation for such a unit would be approximately \$1,500 which would add another \$75.00 at five per cent interest, plus depreciation at five per cent (for a four month period). The additional cost is \$150.00 per 275 hogs marketed, or a total cost of \$236.40 or about 86¢ per hog marketed. This does not include the cost of aeration equipment for the sows, which must be added to the total cost of operation.

**Oxidation ditches** are very similar in costs to aerated lagoons. Both require collection pits and lagoon combinations. The oxidation ditch requires a storage lagoon into which the effluent and sludge may be discharged, after treating. This lagoon needs to be almost as large as that required for aeration unless it is used for storage only, prior to spreading on land.

**Drying, incineration and composting** all require special equipment and operation time. They may be classified as enterprises of their own. As the production unit increases in size, one of these methods may become more applicable if one or two men may be employed to collect the manure and to operate the system on a full-time basis. In each of these systems, the manure should be handled in as dry a condition as possible. This factor alone almost rules them out as acceptable methods for swine manure disposal.

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